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a study of detergent pollution in ground water

FEDERAL HOUSING ADMINISTRATION
JULIAN H. ZIMMERMAN, Commissioner

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A RECONNAISSANCE STUDY OF ANIONIC SURFACTANTS IN GROUND WATER

By

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Geological Survey
Water Resources Division
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FOREWORD

By

JULIAN H. ZIMMERMAN, COMMISSIONER

FEDERAL HOUSING ADMINISTRATION

For some time FHA has recognized the potential problem of detergent pollution in domestic water supplies. Accordingly, our Technical Studies staff requested the United States Geological Survey to determine the severity of the problem.

The study was conducted in six widely separated residential developments.

FHA is pleased to publish this report as further evidence that our Technical Studies Program is engaged in research pertinent to present and future problems affecting the health, safety and comfort of the nation's homeowners.

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INTRODUCTION

The Problem

In recent years it has become evident to those in the water resources field that considerations of quality of many water supplies should include information on the kinds and amounts of organic substances in the water. Some of these substances may be of natural occurrence, but many are the result of man's activities. Included in the latter category are the anionic surfactants, the active ingredients of most synthetic detergents, or syndets. During the past 10 or 12 years the use of syndets in the United States has increased rapidly until, today, they have almost supplanted soaps for both domestic and industrial use. The major type of anionic surfactants, the ABS (alkyl benzene sulfonate) group, is highly resistant to biological degradation, so that the effect of ABS in water may persist over long periods of time. Waste waters may carry these surfactants to surface-water and ground-water supplies with resulting deterioration of the water quality, which includes unpleasant taste and odor, and foaming. Although some studies have been reported in the literature, very little is known concerning the nature and extent of occurrence and movement of the anionic surfactants in waters or of the chemical and physical changes that they undergo after being added to ground and surface waters.

The Project

In March 1959, officials of the Federal Housing Administration and the Geological Survey met to discuss problems relating to anionic surfactants in ground water, with specific reference to the possibility of surfactant movement from septic tanks to water-supply wells in housing development areas. As a result of the discussions, the FHA requested the Geological Survey to conduct a reconnaissance study in six widely separated areas of the United States where it was believed that conditions may be favorable to movement of anionic surfactants in the ground water. The areas selected were the following: Madison County, Ala.; Dade County, Fla.; Anoka and Ramsey Counties, Minn.; Bernalillo and Valencia Counties, N. Mex.; Norfolk and Princess Anne Counties, Va.; and LaCrosse County, Wis. In each of these areas a limited appraisal of the geologic and hydrologic conditions was made, and individual ground-water sources were sampled for determination of the ABS content. In general, each source was selected where the possibility of ABS movement to the water supply appeared to be favorable. Most of the samples collected conformed to the following criteria:

1. Each sample should be collected from a nonartesian well 50 feet or less in depth, which serves an individual house or building.
2. The house should have an individual sewage-disposal system.
3. The housing project should be at least 3 years old.

4. The water supply should not be softened.

5. Information on well construction and location should be available, including approximate distances of wells from septic tanks or tile fields.

6. The aquifer should be relatively permeable to a depth of about 50 feet.

Summary of findings

Analysis of 135 water samples collected from ground-water sources in selected areas of 6 States revealed a range in anionic surfactant content, expressed as ABS, from 0.0 to 4.1 ppm (parts per million). Two or more samples in each of the six States contained appreciable quantities of ABS. More than 20 percent of the samples contained at least 0.2 ppm, and 4 percent of the samples contained more than 1.0 ppm of ABS. Samples from one well in New Mexico and eight wells in Virginia contained ABS in excess of 0.5 ppm. All the ABS values greater than 1.0 ppm occurred in samples from Virginia. (See table 1.)

Because of the limitations of the analytical method, 0.2 ppm is considered the minimum significant concentration of ABS, although some small amount of ABS may be present in samples reported as 0.1 and 0.0 ppm. About 1.0 ppm is believed to be the minimum concentration of ABS in ground waters that will have unpleasant taste or odor for the domestic user.

The distribution of anionic surfactants in the ground water is not uniform, especially in the Virginia and New Mexico areas where relatively high ABS values were observed. Frequently, nearby and even adjacent wells produce water with widely differing concentration of surfactant.

Laboratory determinations made on the samples also included bicarbonate, nitrate, phosphate, specific conductance, and pH. While these constituents ranged widely, there is little apparent correlation with the ABS content.

Acknowledgments

This study was made under the supervision of W. H. Durum, Acting Chief, Quality of Water Branch, Geological Survey. The laboratory analyses were made under the direction of G. B. Magin, Jr., Research Chemist, Geological Survey. Much valuable assistance in furnishing information was provided by officials of the Federal Housing Administration, well drillers, home owners, personnel of the Ground Water and Quality of Water Branches of the Geological Survey, and others. Collection of the water samples was made by Geological Survey personnel.

DESCRIPTION OF AREAS

Alabama

Twenty water samples were collected in the vicinity of Huntsville, Madison County, Ala., which is in the northern part of the State about 14 miles south of the Tennessee State line. Figure 1 shows the locations of the wells and other sources of the water samples. The numbers correspond to those in table 1 (under Alabama), which gives the analytical results and other data for the samples.

The Huntsville area is underlain by massive beds of limestone of Mississippian age. These limestone beds dip gently to the southeast about 20 feet per mile except where structural anomalies exist. Ground water occurs in solution channels in the limestone and in the weathered

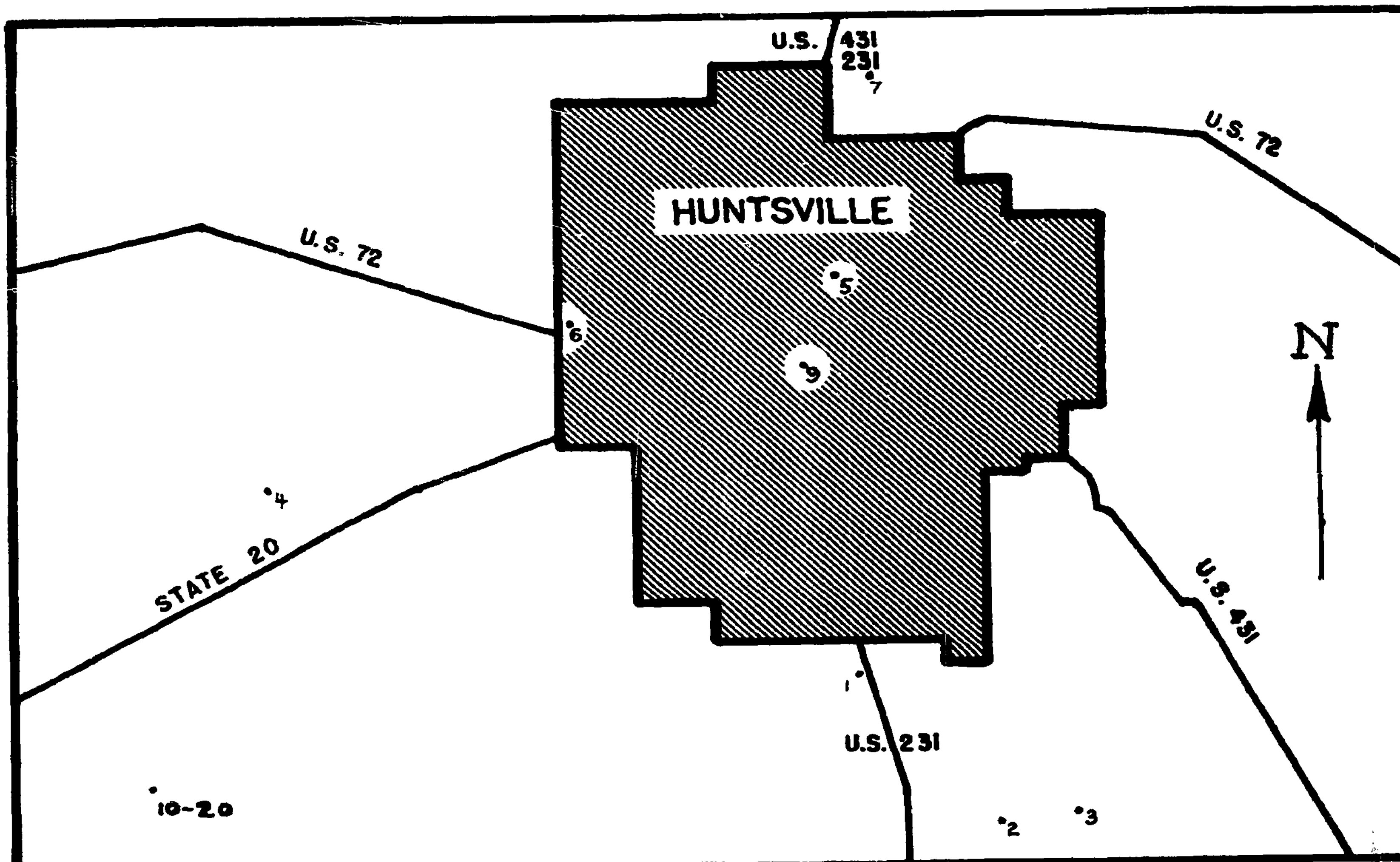


Figure 1.--Sketch map of the Huntsville, Ala. area, showing locations at which ground-water samples were collected.

zone overlying in limestone. Limited domestic supplies in the area are developed in the weathered zone above the bedrock.

The growth of Huntsville has been so rapid in recent years that the city limits frequently have been expanded to include previously outlying communities. Many of the communities outside the city limits have developed privately one or two wells to supply the entire community. Usually the houses in these groups have individual waste-disposal systems. The supply wells of three such communities south of Huntsville -- Weatherly Heights, Lily Flagg community, and Sunset Cove -- were sampled. (See Alabama, wells 1 - 3, table 1.)

A trailer park 3½ miles west of Huntsville, with facilities for about 37 trailers, has one supply well and two septic tanks. This supply (Alabama, well 4, table 1) was also sampled.

Only a few houses within Huntsville have private water supplies and individual waste systems. However, to give an indication as to whether anionic surfactants may be present in the city supply, three samples were taken -- one each from Dallas well, Athens Pike well, and a motel tap representing a composite of wells and springs used in the city supply (Alabama, wells 5 - 6, 8; table 1). Other samples were collected from a well at Alabama A. and M. College (Alabama, well 7, table 1) and Big Spring (Alabama, 9, table 1), formerly used for Huntsville public supply.

As no subdivision or community within the immediate Huntsville area meets all of the sampling criteria, a small settlement about 10 miles southwest of the city was selected for the most intensive study and sampling

(Alabama, wells 11 - 20, table 1). This settlement, the Nolan Drake community, consists of 11 houses, all with individual wells, septic tanks, and grease traps; 3 houses have dry wells for waste water from clothes washers. Most of the houses are on lots 90 to 100 feet wide and are 1 to 4 years old. The distance between the supply well and the septic tank or dry well on each lot averages about 50 feet. The wells in this community were developed in the weathered zone just above the bedrock, which produces limited quantities of water.

Florida

Water samples collected in Florida were from wells in Dade County, 3 in subdivisions north of Miami (Florida, wells 22 - 24, table 1) and 21 in subdivisions in Township 55 South, Range 40 East, south of Miami. (Florida, wells 1 - 21, table 1). Figure 2 shows the locations and lot sizes of the subdivisions south of Miami.

All wells sampled tap the Biscayne aquifer, the hydrologic unit that carries unconfined ground water in southeastern Florida. This aquifer is composed of permeable limestone in the upper part of the Tamiami formation (upper Miocene), the Fort Thompson and Anastasia formations, the Miami oolite, and the Pamlico sand (Pleistocene).

The uppermost limestone unit of the Biscayne aquifer is the Miami oolite, which averages about 20 to 30 feet thick beneath the coastal ridge. It is riddled with solution holes and has a remarkable vertical development and a correspondingly high permeability. Heavy rainfall quickly infiltrates into the rock.

A minor part of the Biscayne aquifer is the Pamlico sand, a veneer of permeable white quartz sand that mantles the coastal ridge as far south

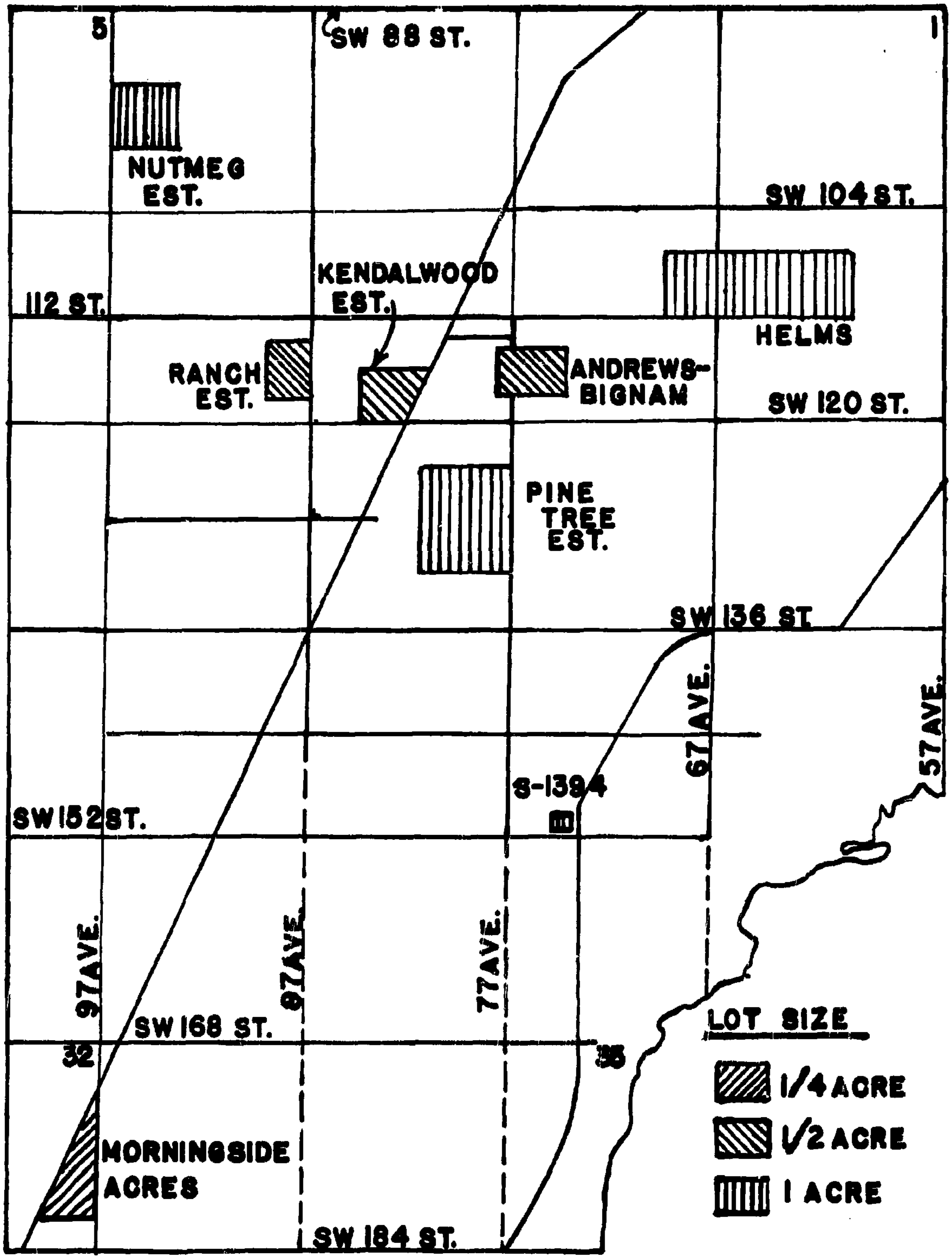


Figure 2.--Sketch map of part of T. 55 S., R. 40 E., Dade County, Fla., showing subdivisions where water samples were collected.

as Coral Gables. In north Dade County the Pamlico sand fills old drainage channels. Where it is well developed the Pamlico sand can yield moderate quantities of water to sandpoint wells.

The Biscayne aquifer is one of the most permeable aquifers investigated by the Geological Survey. It compares with clean, coarse, well-sorted gravel in ability to transmit water. In general, the permeability of the Miami oolite is lower than that of the underlying limestones.

Each of the wells sampled in the southern part of Dade County taps the Miami oolite except for well 1, table 1, which taps the Fort Thompson formation at a depth of 52 feet. In the subdivisions in south Dade County, each house is served by an individual well and septic tank. The distance between the well and the septic tank for houses in this area ranges from about 50 to 75 feet and averages about 60 feet.

In north Dade County the shallow part of the Biscayne aquifer is chiefly quartz sand of lower permeability than that of the Miami oolite; therefore, yields of shallow wells are somewhat smaller and the rate of ground-water movement is somewhat lower than for the areas underlain by the Miami oolite. The houses in the subdivisions of north Dade County where water samples were collected are served by individual septic tanks, but the water supply is furnished by a subdivision water-supply system. The ground-water samples collected in this area were from small, shallow wells used for lawn irrigation (Florida, wells 22 - 24, table 1).

Generally the water table is within 10 feet of the land surface in the Miami area. The water table fluctuates widely throughout the year, generally being highest from July to October and lowest from February to May. Regional ground-water flow is east and southeast toward Biscayne Bay. In areas near major drainage canals, ground-water movement is toward the canals.

Minnesota

Water samples were collected from 11 wells in 2 housing areas in Anoka County -- Thompson Park, and Daily and Hurter Additions -- and from 4 wells in 1 housing area in Ramsey County, Windward Heights Addition 1. Figure 3 shows the locations of the three areas.

The Thompson Park Addition, about 12 miles north of Minneapolis, is in a sand dune area of the Anoka Sand Plain. The latter was formed during the retreat of the so-called Grantsburg sublobe which is probably of the Mankato substage of the Wisconsin glaciation. The Jordan sandstone of Late Cambrian age lies directly below the glacial drift in this area. The gradient of the water table is assumed to be toward the Mississippi River.

The samples in the Thompson Park Addition were from the supply wells of houses built during the first two years of construction, March 1955 to March 1957 (Minnesota, wells 1 - 7, table 1). Lots are 75 x 130 feet in size, the wells are under the back steps of the houses, and the cesspools are in the center of the front-yards, about 50 feet from the supply well. A number of water softeners are used in the area, but only untreated water samples were collected.

The Daily and Hurter Addition, about 9 miles north of Minneapolis, is similar to the Thompson Park area in the Anoka Sand Plain and may also be in a dune area. The glacial drift may be partly underlain by Jordan sandstone and partly by Shakopee dolomite and Oneota dolomite, both of Early Ordovician age. The houses in this addition were built during the summer and fall of 1955 on lots 75 x 130 feet. The wells are under the front steps, and the cesspools are in the back yards, about 50 feet from the supply well. Water softeners are used in many of the houses, but only untreated water samples were collected (Minnesota, wells 8 - 11, table 1).

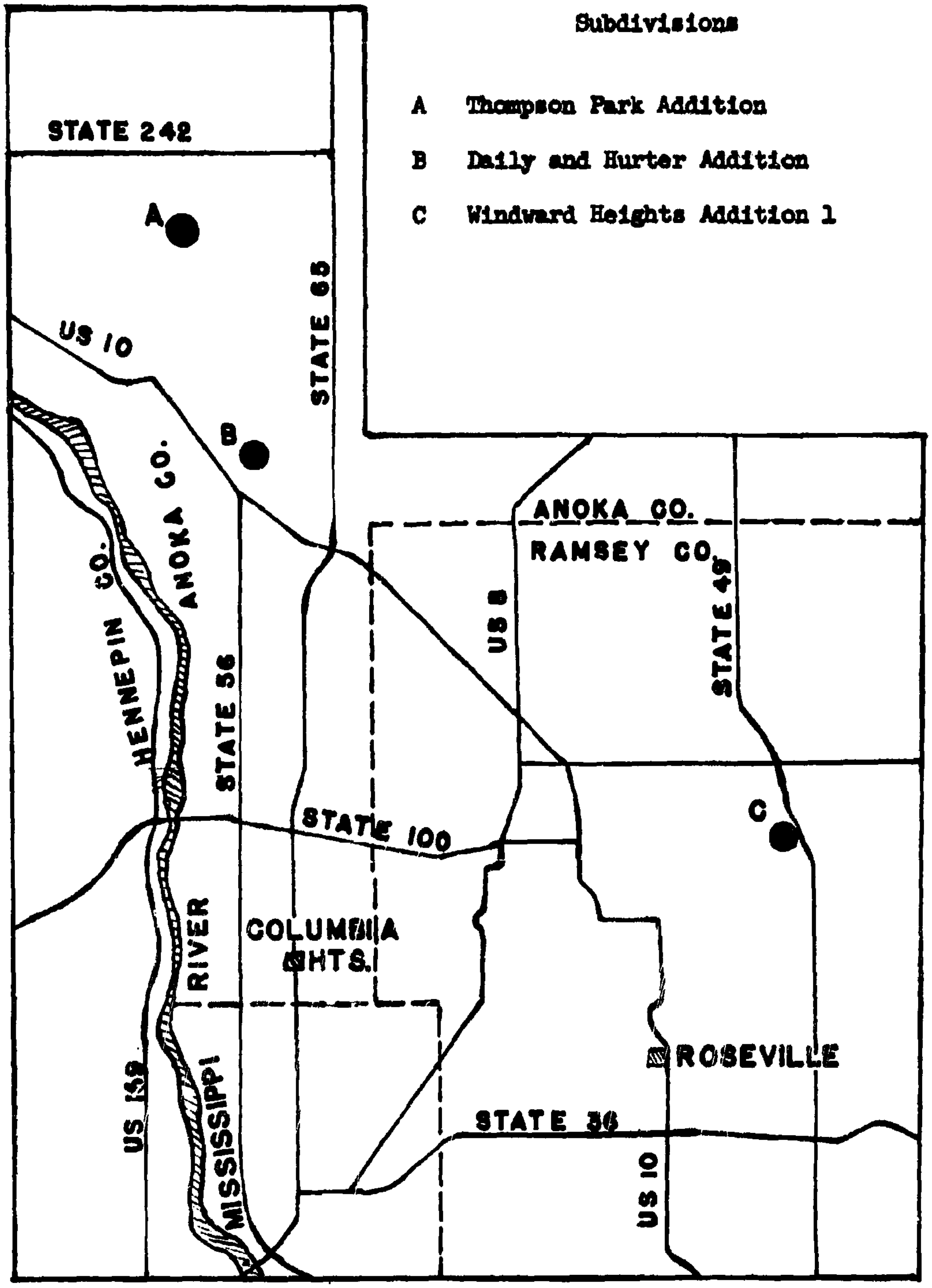


Figure 3.--Sketch map of area north of Minneapolis-St. Paul, Minn., showing locations of subdivisions where water samples were collected.

The Windward Heights Addition 1 is in the north central section of Ramsey County, 6 miles north of St. Paul. The area is on a southeastwardly projecting finger of the Anoka Sand Plain about 0.8 mile wide. Regional ground-water movement is probably toward the Mississippi River; locally the movement is probably toward the lakes of the area.

Houses in the Windward Heights Addition 1 were built during the summer and fall of 1956. The lots are 100 x 150 feet. The wells are under the front steps of the houses and the cesspools are in the back yards. The distance between the well and cesspool is about 60 feet. A few water softeners are used in the area, but only untreated water samples were collected. Analytical results and other data for the water samples (Minnesota, wells 12 - 15) collected in this area are given in table 1.

New Mexico

Water samples collected in New Mexico included 20 from driven wells and 4 from drains in Bernalillo County and 1 from a driven well in Valencia County. Figure 4 shows the location of the sampling sites near Albuquerque in Bernalillo County; the numbers correspond to those under New Mexico in table 1.

All samples were from the alluvium of Recent age in the Rio Grande valley, which consists of unconsolidated gravel, sand, silt, and clay, as much as 130 feet in thickness. The drains, which have been constructed in the alluvium, are ditches 8 to 10 feet deep which collect shallow ground water from the area under the valley floor and prevent the soil from becoming waterlogged. Well 1 (New Mexico, table 1), about a mile east of Los Lunas, was selected to represent an isolated installation.

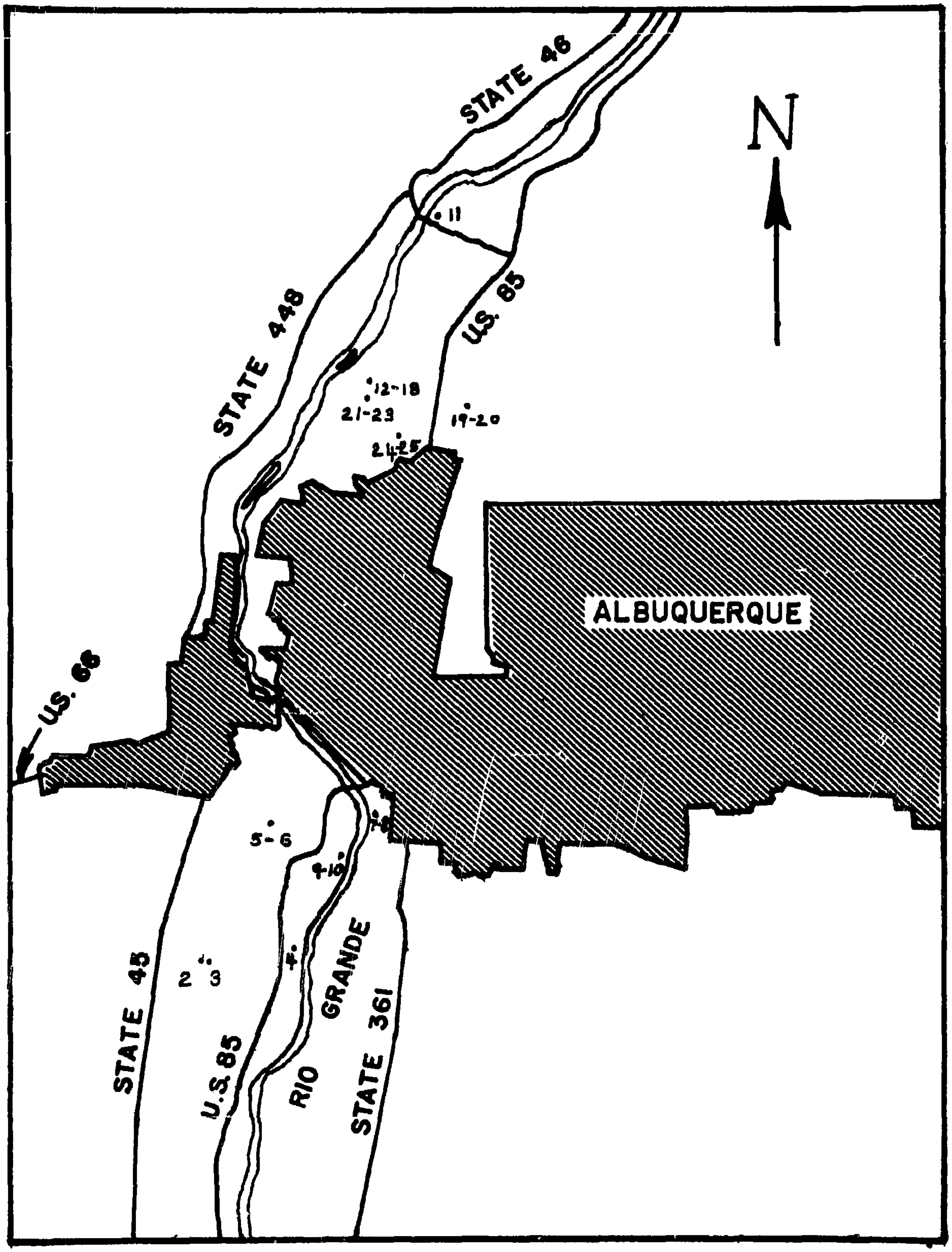


Figure 4.--Sketch map of the Albuquerque, N. Mex. area, showing locations at which ground-water samples were collected.

Samples from wells 7 and 8 (table 1) were collected near the sewage-disposal plant for the city of Albuquerque. The tanks at the plant are believed to leak and build up the water table in that vicinity.

The most intensive sampling was made in the Rob Lee Addition, about 1½ miles north of Albuquerque. Nine samples from shallow wells (New Mexico, wells 12-18, 21-22; table 1) and one drain sample (New Mexico, 23, table 1) at the lower end of the housing development were collected in this area.

Nine well samples were collected from five other heavily populated areas adjoining Albuquerque (New Mexico, wells 2-3,5-6,10, 19-20, 24-25; table 1). Sample 11 in table 1 represents water from the Albuquerque Riverside Drain upstream from most of the residences of the area in order to serve as a rough control. The other drain samples (New Mexico, 4, 9, 23, table 1) were collected at points downstream from housing area; it was thought likely that these would be representative of the shallow ground water in those areas.

Most of the well samples were collected in areas in which each house is equipped with individual well and septic tank or cesspool. Generally samples were collected from wells downgradient from one or more houses with septic tanks. Wherever possible shallow rather than deep wells were selected. The distance between the well and septic tank ranges from about 20 to 100 feet and averages about 50 feet. The reported water level in the wells ranged from 4 to 12 feet below the land surface.

Virginia

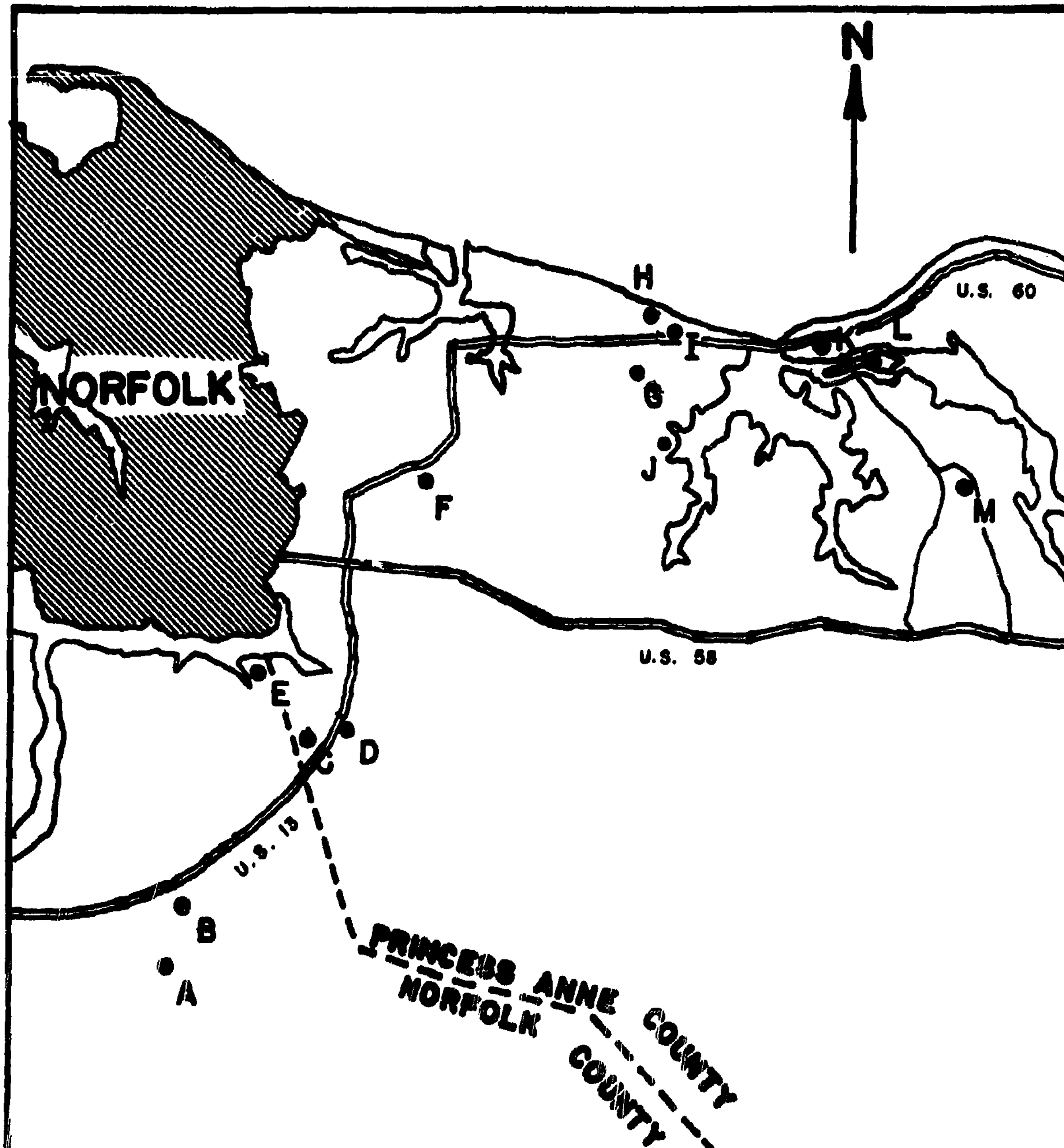
Ground-water samples collected in Norfolk and Princess Anne Counties, Va., were from wells in a number of subdivisions east and south of the city of Norfolk. (See figure 5).

The land surface of this area is flat to gently rolling. The maximum altitude is less than 30 feet above sea level, except for a dune area along the coast. Consequently, the ground water moves slowly to shallow, swampy channels that flow into the drowned stream systems. Recent sand dunes are well developed along the northern border of Princess Anne County on Chesapeake Bay. Their altitudes are generally less than 50 feet except in the Cape Henry area, where crests are as much as 75 feet above sea level.

The surface deposits are composed of Recent and Pleistocene sediments which are underlain by Miocene sand and clay. The Pleistocene deposits consist chiefly of yellow and tan sand and clay, with some blue clay and marly beds containing shells. The maximum thickness is about 50 feet. The Miocene sediments consist of about 650 feet of gray and blue clay and fine sand. Outcrops of Miocene sediments have not been identified in the Norfolk area, but more detailed mapping may show the thick blue clay deposits on Hermitage Point to be of Miocene age. Four subdivisions -- Westview Village, Woodburst, L and J Gardens, and Diamond Lake Estates -- adjoin sand pit lakes where about 10 to 15 feet of sandy sediments are exposed.

Ground-water movement in Norfolk and Princess Anne Counties is assumed to be in the direction of streams or other bodies of water.

The analytical results for the 36 water samples collected from wells in the Norfolk area and other data are given in table 1. The



Subdivisions

A Cresthill
B Westover
C Indian River Gardens
D Westview Village
E Indian River Territory
F Diamond Lake Estates; L and J Gardens
G Bayville Park
H Chesapeake Beach
I Baylake Pines
J Ewell and Hermitage Points
K Lynnhaven Colony
L Broad Bay Island
M Woodhurst

Figure 5.--Sketch map of the Norfolk, Va. area, showing locations of the subdivisions where water samples were collected.

reported depths of the wells ranged from about 15 to 30 feet except for 3 wells that exceeded 50 feet. Several of the owners did not know the depths of their wells, but it was reported that throughout much of the area, especially in the northern part of Princess Anne County, only shallow wells could be used because salty water occurs at greater depths. A typical house where a water sample was collected is 2 to 5 years old, with individual well and septic tank, on a lot about 80 x 125 feet. The well is commonly located at the front of the house and the septic tank in the back yard, about 50 feet from the well.

Many of the owners complained of the quality of the water from the shallow wells. The presence of excessive iron and acidity was generally reported. However, bad odors and tastes were also observed by owners, especially in the Cresthill subdivision. In Cresthill some of the residen drank only bottled water, whereas others had their wells deepened to about 90 feet in order to obtain water which was believed to be of better quality.

In several subdivisions water conditioners are in common use. No samples were collected in Meadowbrook Forest, near the Norfolk Municipal Airport, because practically all of the houses in that subdivision are equipped with water conditioners. However, in Bayville Park several water samples were obtained from houses with water conditioners by collecting untreated water from an outside tap or by bypassing the conditioner.

A representative of a water-conditioning company reported that colored water occurred in the shallow domestic wells in several local areas in Princess Anne County. The samples collected from several of these places (Virginia, wells 16-19, 30-33; table 1) had little or no apparent color at the time of collection.

Wisconsin

Only a few shallow domestic supply wells exist in La Crosse County, Wisconsin, because of a State requirement that the driller of a well must install at least 50 feet of casing if the water is to be used for human consumption. The principal area which meets the sampling criteria is French Island, where 13 of the 15 water samples for La Crosse County were collected (Wisconsin, wells 2-6, 8-15, table 1). One sample was collected just south of La Crosse (Wisconsin, well 1, table 1), and another at Holmen (Wisconsin, well 7, table 1), about 8 miles north of La Crosse. Figure 6 shows the locations of wells from which the samples were obtained and the principal features of the general area. The numbers LaC 1-15 in figure 6 correspond to Wisconsin numbers 1-15 in table 1.

The city of La Crosse is built on a broad sand and gravel terrace that lies between the Mississippi River and its sloughs and lakes and the bluffs that form the edge of the river valley. French Island is close to central La Crosse and has been largely annexed by the city.

The glacial sand and gravel of the valley fill is an excellent source of water to high capacity wells and to small domestic supply wells. The principal source of the water is local precipitation, but some water moves into the valley fill from the underlying sandstone of Cambrian age. The recharge areas, east of La Crosse, are at a much higher elevation than the valley floor, so water in the sandstones is under sufficient head to move upward into the valley fill and be discharged at the rivers.

Ground-water movement on French Island appears to be from the interior of the island toward Coleman Slough, Black River, and Lake Onalaska on the east and towards French Slough and Lake Onalaska on the west (See figure 6.)

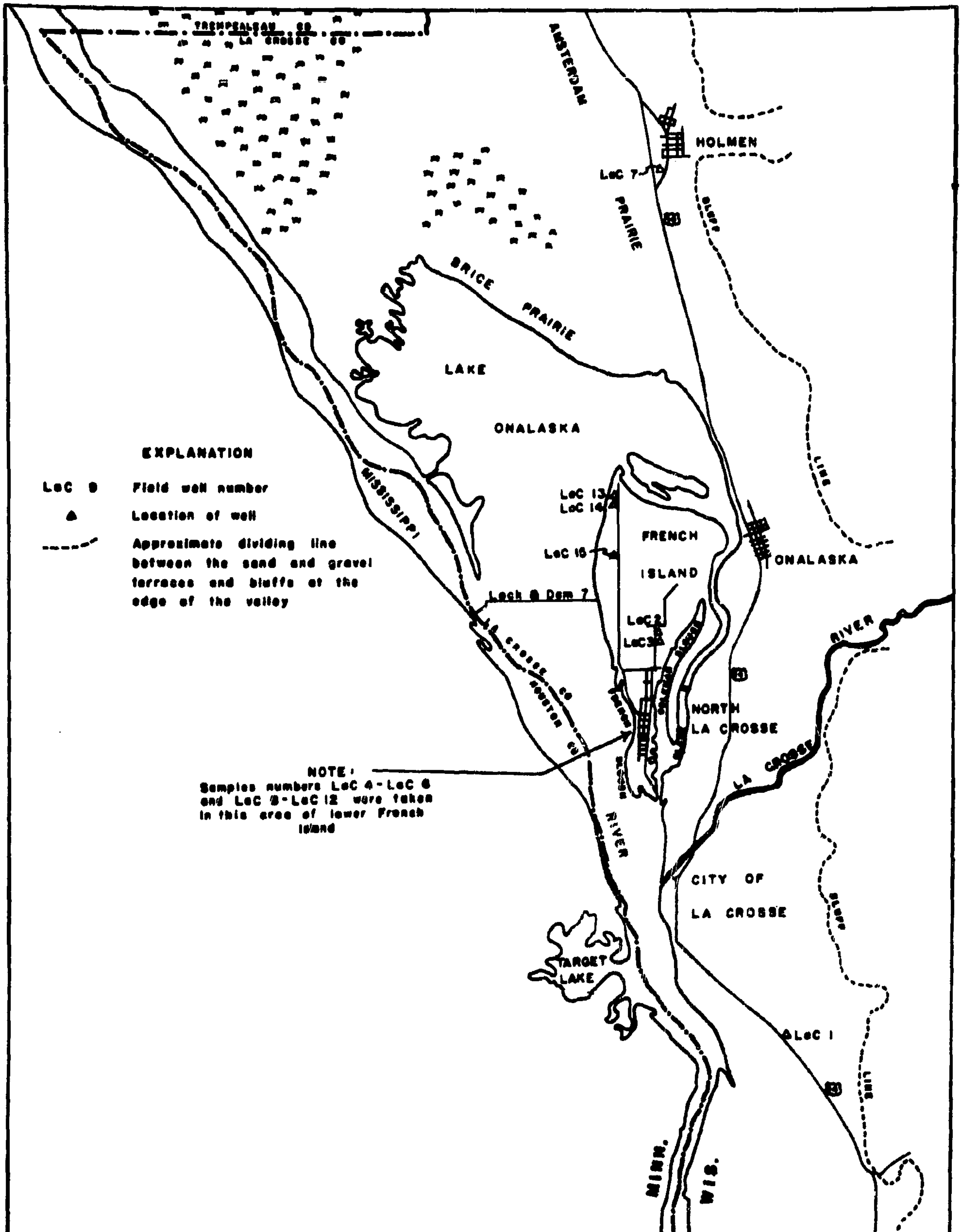


Figure 6.--Sketch map of the La Crosse, Wis. area, showing location of wells from which water samples were collected.

The oldest houses on French Island are at the southern end of the island. Many are low-cost type built by the owners themselves. The houses on the northern part of the island are larger, newer, and more expensive. Most of the wells on the island are driven wells with sand points. All residents reported water of good quality. The individual sewage-disposal systems consist of septic tank and dry well, with some houses having two septic tanks and two dry wells. One of the latter for receiving waste water from the kitchen and the other for waste water from bath and laundry. Well 7, table 1, is a drilled well which serves three houses at Holmen.

METHOD OF ANALYSIS

The anionic surfactant content of the water samples was determined as ABS by the methylene blue method. This procedure is based upon the reaction between the surfactant anion and the methylene blue cation to produce a salt which is soluble in chloroform. The color intensity of the blue salt is measured with a spectrophotometer; the concentration of the surfactant is proportional to the optical density of the chloroform solution and is determined by reference to standard ABS samples. The method is subject to both positive and negative interferences, although the positive ones are much more common. Thus the apparent ABS content by this method may represent a maximum rather than an exact ABS concentration value. (See pages 24-25.)

In order to determine if there is interference in the method by the anionic organic substances that produce color in natural waters, a sample of swamp water was collected and analyzed for ABS content. This sample was presumed to be free of anionic surfactant. The color of the

filtered sample was 85 units and the apparent ABS was 0.1 ppm. Color in ground waters usually has a range of 0 to about 10 units, so it is probable that there is no significant interference from this source.

The all-purpose syndet that is commonly used for household purposes is composed of 20 to 40 percent anionic surfactant, 30 to 50 percent of molecularly dehydrated phosphates (largely sodium tripolyphosphate), as much as 10 per cent of sodium silicate, and sodium sulfate in varying proportions; many also have lesser amounts of sodium carboxymethylcellulose, condensed amines, and minor amounts of bleaches and dyes. Because of the large percentage of phosphates in the composition of many syndets, the water samples collected for ABS analysis were also analyzed for total phosphate.

FINDINGS

The anionic surfactant content, as ABS, for 135 samples of ground-water sources from selected areas in six States ranged from 0.0 to 4.1 ppm. (See table 1.) The range in ABS content by States follows:

State	Number of samples	Range in ABS (ppm)
Alabama	20	0.0 - 0.4
Florida	24	0.0 - 0.5
Minnesota	15	0.0 - 0.4
New Mexico	25	0.0 - 0.8
Virginia	36	0.0 - 4.1
Wisconsin	15	0.0 - 0.4

Two or more samples in each of the six areas contained 0.2 ppm or more of ABS. The distribution at each concentration level is given in the following table:

ABS in ppm	Number of samples	Percentage of total
0.0	56	41
.1	51	38
.2	12	9
.3	1	1
.4	5	4
.5	1	1
.6	0	0
.7	0	0
.8	2	1
.9	1	1
1.0	0	0
More than 1.0	6	4
Totals	135	100

It will be seen that 21 percent of the ABS values are greater than 0.1 ppm, and 4 percent exceed 1.0 ppm.

The samples from Virginia had 42 percent with ABS greater than 0.1 ppm and 17 percent greater than 1.0 ppm. All the ABS values exceeding 1.0 ppm were for samples from wells in three subdivisions: Bayville Park, Indian River Territory, and Indian River Gardens. It is also significant that the sample collected in Westview Village from a well only about one year old had an ABS content of 0.8 ppm.

The samples from wells in Bayville Park (Virginia) ranged in ABS content from 0.1 to 3.5 ppm, with the highest value for water from a well located at the eastern edge of the subdivision. The direction of ground-water movement is believed to be toward the east in this area. Other high ABS concentrations occurred in water from wells near the center of the subdivision, where one owner reported that a septic tank on a lot across the street was not functioning properly. Foam was observed on the water samples having an ABS content of 2.9 ppm or more, but none was observed at the 1.3 ppm level. There was no ABS value between 1.3 and 2.9 ppm, so it is not possible to set an exact concentration at which the foam appears under these conditions. Further study would probably determine an approximate minimum ABS concentration at which foam is apparent in this area.

Only three water samples were collected in Indian River Territory (Virginia). The ABS concentrations were 1.2, 0.1, and 0.2 (Virginia, wells 1-3, table 1). The highest value was for water from a well near the Eastern Branch Elizabeth River; the direction of ground-water movement is probably toward the river.

The water sample collected in Indian River Gardens (Virginia) had the highest ABS concentration determined in this study, 4.1 ppm. The well is near King's Creek, downgradient from much of the subdivision. The owner reported that acidity and excessive iron were problems for both that well and others in the area. Foam was observed on the water at the time of collection. The ABS determination of this sample was repeated four times from April 9 to May 1, 1959, without any loss of ABS; the average value remained 4.1 ppm.

An interesting situation exists in New Mexico where the well 5 (table 1) water sample was collected. The relatively high ABS concentration of 0.8 ppm appears to be the result of the location of the well about 6 feet from a cesspool that receives waste water from a clothes washer. The general direction of ground-water movement in the vicinity places the well downgradient from the cesspool.

ABS determinations were made for 26 additional samples, not a part of this project, collected in February and April 1959 from wells in California, Indiana, Maryland, Michigan, and Oregon. Seven samples from Maryland and one sample from Michigan had ABS values of 0.2 ppm or more. The maximum ABS for this group, 2.9 ppm, was found in water from a shallow well in Maryland.

Other determinations made on the 135 water samples from the 6 States included bicarbonate, nitrate, phosphate (total), specific conductance, and pH. These results, given in table 1, show a wide range of values. Bicarbonate ranges from 0 to 459 ppm, nitrate from 0.0 to 70 ppm, phosphate from 0.0 to 2.3 ppm, specific conductance from 59.8 to 2,240 micromhos per centimeter at 25° C., and pH from 4.5 to 8.4. Water samples with high ABS concentrations tend to have high nitrate content, low bicarbonate content, and pH less than 7.0. For most of the samples there is no apparent relationship between ABS and phosphate or specific conductance.

SIGNIFICANCE OF FINDINGS

The apparent ABS content of the water is as likely to be 0.1 as 0.0 ppm for deep wells, isolated wells, and ground-water sources used for public supplies. Further, all samples with specific conductance of

1,000 micromhos or more have apparent ABS of at least 0.1 ppm. Since it is known that the methylene blue method for determination of ABS-type compounds is subject to positive errors, it is possible that water with apparent ABS of 0.1 ppm may actually contain little or no anionic surfactant. Because of these facts it seems reasonable to assume that 0.2 ppm is the lowest ABS value reported which should be considered significant. An ABS concentration of about 1.0 ppm in ground water is the minimum level at which undesirable characteristics for domestic users may become evident.

The question arises as to why only in the Virginia area were ground waters found to contain 1.0 ppm or more of anionic surfactant. Two possible general factors are suggested:

1. Only in the Virginia area is the drainage so poor. This may reduce velocity of ground-water movement and allow build-up of ABS concentrations locally where other conditions favor such build-up.
2. Only in the Virginia area are the ground waters generally acidic (pH below 7.0). This is significant because troublesome concentrations of ABS in ground waters may be limited to areas where the ground waters are acidic.

A more wide-spread reconnaissance study including other States would probably locate other areas of high ABS in ground waters.

It is believed that the amount of ABS in ground water is related to depth of well, distance between septic tank or cesspool and well, lot

size, depth to water table, velocity and direction or ground-water movement, age of house and well, size of family, water and syndet usage, precipitation, and nature of the aquifer. Plots were made of ABS content versus pH, nitrate, phosphate, bicarbonate, specific conductance, reported depth of well, and age of house. However, the data available are too limited in range or completeness to make adequate correlations.

CONCLUSIONS AND RECOMMENDATIONS

Analytical results based upon 135 ground-water samples collected in scattered areas in 6 States show that about 5 percent of the samples contain anionic surfactants in quantities sufficient to exhibit unpleasant characteristics of bad taste, odor, or foaming. About 15 percent of the total contain appreciable amounts of surfactant, but not in quantities sufficient to produce unpleasant characteristics. The remaining samples, approximately 80 percent of the total, contain either no surfactant or an insignificant amount of surfactant. Most of the samples were collected from wells where conditions were believed to be favorable for the presence of surfactant in the water.

A high concentration of anionic surfactant may be accompanied by a relatively high concentration of nitrate in the water. Total phosphate content and specific conductance were not found to have any relation to the presence of surfactant in water. A high concentration of surfactant may be found largely in waters with low bicarbonate content and with pH below 7.0.

The presence of anionic surfactants in well waters is probably influenced by a number of factors; some of these are: source and quantity of surfactant, distance between source of surfactant and well, depth of

well, direction and velocity of ground-water movement, mineral composition and adsorption capacity of the sediments in and above the aquifer, and time required for surfactant transport.

Additional studies relating to anionic surfactants in ground waters should include: the extent of occurrence; short-time variations; long-term trends; and chemical, physical, and other factors affecting the movement and quantities of anionic surfactant in soil and water. Involved in such studies are: amount and nature of surfactants used, dilution of surfactants by waste water and precipitation, controlled tracer studies, correlation with other constituents in water, and correlation with geologic and hydrologic characteristics.

APPENDIX

Table 1. --Chemical and physical characteristics of water from selected ground-water sources
/Analyses by Geological Survey/

Number	Source	Street address	Subdivision	County	Reported depth of well (feet)	Year constructed	Date of collection	Temperature (°F)	Parts per million: Bicarbonate (HCO_3)	Parts per million: Nitrate (NO_3)	Parts per million: Phosphate (PO_4)	Parts per million: Alkyl benzene sulfonate (ABS)	Specific conductance (micromhos at 25°C)	pH
						ALABAMA								
1	Well		Lily Flag	Madison	59	1955	Apr. 8, 1959	74	187	8.8	0.2	0.1	352	7.6
2	do.		Weatherly Heights	do.	98	1956	8	65	283	.0	.1	.0	473	7.7
3	do.		Sunset Cove	do.	160	1955	8	64	156	1.9	.2	.1	281	7.6
4	do.	Crisco Trailer Park		do.	68	1955	8	64	33	3.1	.2	.0	59.8	6.7
5	do.		Huntsville	do.	102	1956	9	63	148	5.5	.3	.1	259	7.5
6	do.		do.	do.	116	1956	9	62	120	5.3	.1	.1	209	7.7
7	do.	State A. and M. College		do.	154	1908(?)	9	63	149	6.4	.2	.0	260	7.7
8	do.	Kay's Motel	Huntsville	do.	...	...	9	74	128	6.1	.2	.0	222	7.5
9	Spring		do.	do.	...	...	9	63	177	7.5	.1	.0	313	7.6
10	Well	Lot 1	Nolan Drake	do.	...	...	8	66	188	.0	.0	.0	306	7.2
11	do.	Lot 2	do.	do.	...	...	8	83	155	.0	.2	.0	250	7.3
12	do.	Lot 3	do.	do.	...	...	8	65	145	.0	.1	.0	236	7.3
13	do.	Lot 4	do.	do.	...	...	8	61	144	.0	.1	.1	237	7.3
14	do.	Lot 5	do.	do.	...	...	8	72	206	.0	.1	.1	415	7.4
15	do.	Lot 7	do.	do.	...	...	8	66	148	.9	.1	.0	239	6.9
16	do.	Lot 8	do.	do.	...	...	8	65	135	.9	.2	.1	218	7.6
17	do.	Lot 11	do.	do.	40	1956(?)	8	64	58	17	.1	.2	141	6.5
18	do.	Lot 12	do.	do.	40	1956(?)	8	64	154	.0	2	.0	241	7.5
19	do.	Lot 13	do.	do.	60	1956	8	64	114	32	.2	.1	243	7.3
20	do.	Lot 14	do.	do.	60	1956	8	63	82	67	.1	.4	291	6.9
						FLORIDA								
1	Well	10650 SW 68 Ave	Helms	Dade	52	1950	Apr. 7, 1959	78	258	0.0	0.1	0.0	477	8.0
2	do.	6835 SW 112 St	do.	do.	25	1954	7	76	270	.0	.1	.0	506	7.7
3	do.	11030 SW 60 Ave	do.	do.	20	1955	7	78	341	7.0	.0	.2	736	7.9
4	do.	10685 SW 63 Ave	do.	do.	25	1950	7	78	266	.0	.0	.0	509	7.8
5	do.	11300 SW 77 Ave	Andrews	do.	20	1956	7	77	300	4.7	.0	.1	576	8.0
6	do.	7701 SW 118 St	do.	do.	20	1951	7	79	275	2.6	.0	.0	510	7.8
7	do.	7837 SW 117 St	do.	do.	20	1954	7	77	280	2.2	.0	.0	526	7.8
8	do.	6735 SW 118 St	Ranch Est.	do.	25	1953	7	78	258	.9	.0	.0	517	7.9
9	do.	7801 SW 132 St	Pine Tree Est.	do.	25	1955	7	78	278	6.4	.0	.1	559	7.8
10	do.	7840 SW 128 St	do.	do.	21	1953	7	79	275	15	.0	.1	601	7.9
11	do.	9501 SW 93 Ct	Nutmeg Est.	do.	35	1955	7	78	268	.0	.1	.0	479	7.9
12	do.	9500 SW 94 Ct	do.	do.	20	1955	7	76	303	1.0	.1	.0	549	7.9
13	do.	116 St. and SW 82 Ave.	Kendalwood Est.	do.	28	1958	7	80	275	8.2	.0	.1	520	7.9
14	do.	8275 SW 120 St	do.	do.	30	1956	7	80	272	4.6	.0	.0	517	7.9
15	do.	14920 SW 74 Ave.	8-1384	do.	20	1956	7	78	254	.0	.0	.0	505	7.8

Table 1. --Chemical and physical characteristics of water from selected ground-water sources--Continued

/Analyses by Geological Survey/

Number	Source	Street address	Subdivision	County	Reported depth of well (feet)	Year constructed	Date of collection	Temperature (°F)	Parts per million: Bicarbonate (HCO_3)	Nitrate (NO_3)	Phosphate (PO_4)	Alkyl benzene sulfonate (ABS)	Specific conductance micromhos at 25°C)	pH
FLORIDA--Continued														
16	Well	9750 SW 183 St	Morningside Acres	Dade	20	1953	Apr. 8, 1959	77	253	4.3	0.0	0.0	469	7.9
17	do.	9760 SW 182 St	do.	do.	20	1953	8	78	252	4.3	.0	.0	464	7.9
18	do.	9720 SW 181 St	do.	do.	20	1952	8	78	372	5.1	.0	.0	468	7.8
19	do.	18330 SW 97 Ave	do.	do.	26	1954	8	78	243	5.7	.0	.1	478	8.0
20	do.	9710 SW 180 St	do.	do.	20	1952	8	78	251	4.7	.0	.0	452	7.9
21	do.	18300 SW 98 Ave	do.	do.	20	1956	8	78	251	2.9	.0	.0	454	7.8
22	do.	19440 NW 7 Ave	Norwood	do.	42	1956	8	79	287	.0	.1	.1	565	7.7
23	do.	19430 NW 4 Ave	Sierra Mirada	do.	41	1956	8	78	295	.0	.0	.5	629	7.8
24	do.	1030 NE 177 Terrace	Windward Manor	do.	30	1956	8	80	242	.0	.0	.2	557	7.8
MINNESOTA														
1	Well	571 Northdale Blvd.	Thompson Park	Anoka	42	1955	Apr. 21, 1959	51	80	39	0.1	0.0	184	7.7
2	do.	11560 Kumquat St. NW.	do.	do.	39	1955	21	52	245	7.2	.1	.4	590	7.9
3	do.	11841 Juniper St. NW.	do.	do.	36	1955	21	53	243	34	.1	.2	561	7.9
4	do.	11756 Larch St. NW.	do.	do.	35	1956	21	54	112	15	.2	.0	256	8.1
5	do.	11901 Magnolia St. NW	do.	do.	37	1957	21	52	104	19	.1	.1	338	7.6
6	do.	11581 Juniper St. NW	do.	do.	34	1956	21	50	75	29	1.5	.0	246	7.6
7	do.	11331 Kumquat St. NW	do.	do.	49	1956	21	50	67	5.2	.1	.0	212	7.6
8	do.	106-91 Ave. NE	Daily and Easter	do.	33	1955	21	53	126	56	.1	.1	413	7.7
9	do.	132-91 Ave. NE	do.	do.	33	1955	21	50	76	12	.2	.0	253	7.1
10	do.	156 Aurelia Circle	do.	do.	33	1955	21	50	156	6.9	.0	.0	341	7.7
11	do.	122-92 Ave. NE	do.	do.	33	1955	21	51	119	18	.1	.1	339	7.9
12	do.	321 Dennison Dr	Windward Heights	Ramsey.	60	1956	22	46	98	14	.1	.1	207	7.5
13	do.	300 Dennison Dr	do.	do.	60	1956	22	45	121	25	.1	.1	298	7.9
14	do.	312 Lilac Lane	do.	do.	60	1956	22	47	112	14	.0	.1	267	7.5
15	do.	360 Dennison Dr	do.	do.	60	1956	22	45	142	12	.2	.1	304	7.8
NEW MEXICO														
1	Well	....	Los Lunas	Valencia.	58	1954	Apr. 16, 1959	60	202	0.0	0.1	0.0	577	8.1
2	do.	3133 Wilkinson Rd	....	Bernalillo	42	1952	16	60	354	.0	.1	.0	913	8.1
3	do.	3129 Barbon Rd.	....	do.	45	1945	16	62	319	.0	.0	.1	1,270	8.1
4	Drain	Barcelona Rd	....	do.	..	....	16	59	171	.0	.4	.2	482	8.1
5	Well	1825 Quiet Lane	....	do.	37	1951	16	60	336	.0	2.3	.8	1,740	7.9
6	do.	1828 Quiet Lane	....	do.	36	1953	16	62	388	.0	1.1	.1	2,010	8.0
7	do.	226 Smith Ave	Albuquerque	do.	20	1954	16	55	198	.0	.1	.1	507	7.8
8	do.	211 Smith Ave	do.	do.	35	1950	16	56	200	.9	.2	.4	551	7.7
9	Drain	....	....	do.	..	....	16	55	170	.0	.2	.0	454	8.0
10	Well	842 Riverside	....	do.	40	1946	16	58	156	.0	.0	.1	464	8.2

Table 1. --Chemical and physical characteristics of water from selected ground-water sources--Continued
[Analyses by Geological Survey]

Number	Source	Street address	Subdivision	County	Reported depth of well (feet)	Year constructed	Date of collection	Temperature (°F)	Parts per million: Bicarbonate (HCO_3)	Parts per million: Nitrate (NO_3)	Parts per million: Phosphate (PO_4)	Parts per million: Alkyl benzene sulfonate (ABS)	Specific conductance micromhos at 25°C)	pH
				NEW MEXICO--Continued										
11	Drain....	Corrales Rd	....	Bernalillo	..	......	Apr. 17, 1959	54	177	0.0	0.2	0.0	510	8.0
12	Well	1411 N. El Prado........	Rob Lee	..do.....	45	1951	15	59	186	.0	.2	.0	508	7.9
13	..do.....	6021 Redondo	..........do........	..do.....	44	1956	15	57	196	.0	.2	.0	506	7.9
14	..do.....	5926 El Prado	..........do........	..do.....	45	1950	15	58	201	.0	.1	.0	549	8.1
15	..do.....	5916 El Prado........	..........do........	..do.....	36	1950	15	57	177	.0	.1	.0	464	7.9
16	..do.....	5906 El Prado........	..........do........	..do.....	35	1952	15	64	159	.0	.1	.0	421	8.0
17	..do.....	6012 Redondo	..........do........	..do.....	48	1950	15	59	267	.0	.6	.0	964	8.0
18	..do.....	6002 Redondo	..........do........	..do.....	40	1950	15	59	250	.0	.5	.0	830	7.9
19	..do.....	137 Carlito........	....	..do.....	18	1950	17	59	430	.0	.1	.1	1,180	7.8
20	..do.....	136 Velarde........	....	..do.....	45	1948	17	58	398	.0	1.3	.1	1,140	7.9
21	..do.....	1401 El Portal........	Rob Lee	..do.....	42	1956	15	59	221	.0	.2	.0	641	8.0
22	..do.....	1301 El Portal........	..........do........	..do.....	45	1955	15	58	316	.0	2.0	.0	864	8.0
23	Drain....	Rio Grande Blvd........	..........do........	..do.....	..	......	15	63	348	.0	.1	.1	1,020	8.0
24	Well	803 Solar Rd	Lee Acres	..do.....	35	1951	17	60	459	.0	.1	.1	1,240	7.8
25	..do.....	756 Fairway Rd........	..........do........	..do.....	55	1949	17	58	324	.0	.1	.3	1,100	8.1
				VIRGINIA										
1	Well	108 S. Commonwealth Ave.	Indian River Terr......	Norfolk..	23	1956(?)	Mar. 31, 1959	57	30	32	0.2	1.2	277	6.5
2	..do.....	115 S. Commonwealth Ave.	..........do........	..do.....	60	......	31	60	19	8.6	.2	.1	296	6.2
3	..do.....	128 Sparrow Rd........	..........do........	..do.....	..	1955	Apr. 1, 1959	64	70	34	.1	.2	322	6.8
4	..do.....	1317 East Port	Westview Village	Princess Anne	15	1958	1	59	40	9.3	.2	.8	342	6.4
5	..do.....	2716 West Leland........	Indian River Gardens...	..do.....	..	1956(?)	1	52	24	35	.3	4.1	306	6.0
6	..do.....	1104 Wadena St........	Westover	Norfolk..	82	1957(?)	1	58	429	.0	.2	.1	1,030	7.6
7	..do.....	1105 Wadena St........	..........do........	..do.....	15	......	1	57	20	.0	.4	.0	130	6.1
8	..do.....	557 River Creek Rd........	Cresthill........	..do.....	15	1956(?)	1	60	4	2.6	.0	.1	442	5.0
9	..do.....	720 Potter St........	..........do........	..do.....	25	1956(?)	1	60	36	.0	.0	.0	110	6.6
10	..do.....	702 Marcus St........	..........do........	..do.....	..	1956(?)	1	60	6	.0	.0	.0	425	5.8
11	..do.....	214 Linkhorn Rd........	Woodhurst	Princess Anne	30	......	2	63	0	38	.0	.2	335	4.5
12	..do.....	211 Linkhorn Rd........	..........do........	..do.....	..	......	2	61	16	23	.1	.2	407	6.1
13	..do.....	202 Linkhorn Rd........	..........do........	..do.....	..	1957(?)	2	62	19	35	.1	.1	296	6.4
14	..do.....	207 Indian Run Rd	..........do........	..do.....	30	1957(?)	2	64	16	25	.1	.0	177	6.6
15	..do.....	205 Strawberry Lane........	..........do........	..do.....	30	1958	2	62	18	35	.1	.1	197	6.3
16	..do.....	Lot 87........	Broad Bay Colony	..do.....	104	1953	2	61	159	.0	.0	.1	1,410	7.5
17	..do.....	318 Lynn Rd	Lynnhaven Colony	..do.....	..	......	2	61	168	.0	.0	.1	2,240	7.5
18	..do.....	309 Lynnhaven Dr	..........do........	..do.....	..	......	2	63	154	.0	.2	.2	986	7.4
19	..do.....	109 Lynnhaven Circle	..........do........	..do.....	..	1955(?)	2	63	177	.0	.4	.0	534	7.6
20	..do.....	513 Battery	Baylake Pines........	..do.....	..	1957	2	60	42	.7	.0	.1	428	6.4

Table 1. --Chemical and physical characteristics of water from selected ground-water sources--Continued

/Analyses by Geological Survey/

Number	Source	Street address	Subdivision	County	Reported depth of well (feet)	Year constructed	Date of collection	Temperature (°F)	Parts per million: Bicarbonate (HCO_3)	Nitrate (NO_3)	Phosphate (PO_4)	Alkyl benzene sulfonate (ABS)	Specific conductance micromhos at 25°C)	pH
VIRGINIA--Continued														
21	Well	1523 N. James	Bayville Park	Princess Anne	30	1954	Apr. 2, 1959	60	11	0.0	0.2	0.1	104	6.1
22	..do....	1502 N. James	do.	..do....	28	1954	2	59	10	29	.4	.9	218	5.9
23	..do....	1402 E. James	do.	..do....	20	1954	2	59	14	22	.3	3.5	236	5.8
24	..do....	1608 James	do.	..do....	..	1954	2	59	19	.0	.3	1.3	154	6.1
25	..do....	1611 James	do.	..do....	..	1954	2	59	12	2.0	.5	.2	99.4	6.2
26	..do....	1608 Clyde	do.	..do....	25	1954(?)	2	62	14	17	.5	3.3	206	6.0
27	..do....	1509 Clyde	do.	..do....	25	1954	2	58	14	1.4	.4	.4	152	6.0
28	..do....	1723 James Court	do.	..do....	30	1955	2	60	14	3.7	.1	.1	143	6.1
29	..do....	1610 Clyde	do.	..do....	..	1954	2	60	15	19	.4	2.9	225	5.9
30	..do....	511 Lookout Rd	Chesapeake Beach	..do....	14	....	2	62	59	.0	.4	.2	280	6.8
31	..do....	20 Ewell Point	Ewell Point	..do....	..	....	3	..	23	22	.1	.1	241	6.3
32	..do....	Laurel Cove	do.	..do....	..	....	3	58	19	17	.3	.0	245	6.2
33	..do....	26 Hermitage	Hermitage Point	..do....	15	1956	3	..	12	.0	.2	.1	121	5.5
34	..do....	208 Fairlawn Ave	L. & J. Gardens	..do....	25	....	3	58	11	.0	.2	.0	129	5.8
35	..do....	306 Sanford	Diamond Lake Est	..do....	25	1957	3	60	130	.0	.3	.0	274	7.1
36	..do....	410 Anoka	do.	..do....	25	1957(?)	3	60	117	.0	.3	.0	238	7.5
WISCONSIN														
1	Well	205 Monmon Coulee Rd	La Crosse	La Crosse	47	1947	Apr. 9, 1959	57	157	70	0.6	0.2	506	8.1
2	..do....	2524 N. Bainbridge	French Island	..do....	50	1954	9	55	92	31	.2	.0	240	8.1
3	..do....	2520 N. Bainbridge	do.	..do....	35	....	9	56	83	23	.2	.1	230	8.1
4	..do....	1730 N. Bainbridge	do.	..do....	55	1947	9	55	45	32	.3	.1	228	8.0
5	..do....	1730 Caroline	do.	..do....	20	1950	9	55	31	1.2	.2	.0	154	7.2
6	..do....	1737 Caroline	do.	..do....	25	1951	9	62	[a]40	24	.3	.0	152	8.4
7	..do....	....	Holman	..do....	84	1947	10	53	207	22	.4	.1	432	7.9
8	..do....	109 Sparbeck	French Island	..do....	37	1952	10	55	80	36	.3	.1	304	8.2
9	..do....	117 Sparbeck	do.	..do....	40	1951(?)	10	55	65	44	.2	.1	316	7.4
10	..do....	126 Washburn	do.	..do....	35-40	1952	10	58	72	66	.4	.1	352	7.6
11	..do....	1209 Caroline	do.	..do....	35-40	1939	10	53	94	44	.1	.1	442	7.8
12	..do....	1335 Bainbridge	do.	..do....	30	1957	11	55	57	51	.3	.1	316	7.7
13	..do....	Upper W. French Is. Rd	do.	..do....	40	1934	10	55	53	14	.6	.4	184	8.2
14	..do....	do.	do.	..do....	42	1939	11	55	52	39	.2	.1	214	7.4
15	..do....	do.	do.	..do....	35	1956	11	56	91	19	.3	.1	170	8.2

a Includes equivalent of 4 parts per million of carbonate (CO_3).